Preliminary

Some Mechanical Properties of Wood under Superheated Steam*[1]

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(Received May 31, 2002)

Keywords : superheated steam, strain recovery, residual stress, stress relaxation, high temperature

Introduction

Two methods of heating at temperatures above 100°C have been attempted to keep wood radially compressed permanently, i.e., the permanent fixation of wood deformation. One is high pressure saturated steam heating[1)] for wet wood and the other is dry heating[2)] for oven dried wood. These methods have some difficulties in that it takes long time for the latter to achieve the permanent fixation, while for the former wet wood has to be used though the fixation is completed in a short time. To avoid such problems, and to enable practical application, the fixation of deformation of wood should be made in the air dried condition instead of the two extremes of wet and oven dried states.

The purpose of this study is to provide basic information on the fixation of compressive deformation of wood in an air dried condition above 100°C. To this end, we examined how the deformation was fixed and how the residual stress appeared during the fixation process with superheated steaming above 100°C.

Experimental

Oven dried Sugi (*Cryptomeria japonica* D. Don) wood specimens with an average density of 0.30 g/cm^3 were used. The size of specimens was 2 cm in the tangential direction (T) by 2 cm in the radial direction (R) by 1 cm in the longitudinal direction (L). After the specimens were equilibrated with ambient temperatures between 120 and 180°C and relative humidity between 0 and 100% by the use of superheated steam, they were radially compressed to measure the stress strain relationship and the stress relaxation at 50% compression, followed by boiling of the specimens for 30 min to determine their strain recovery.

Results and discussion

The stress strain diagrams at a temperature above 100°C gradually changed in shape from the irregular dried wood type to the smooth wet wood type as the relative humidity increased from 0 to 100%. The yield stresses and Young's moduli obtained from the stress-strain diagrams were related linearly, though they decreased noticeably with increasing relative humidity. Increased temperature and relative humidity greatly accelerated the stress decay with time in the stress relaxation measurement, which suggested that the wood cell wall polymer decomposed faster with superheated steam of higher temperatures and higher relative humidity. It is convenient to use strain recovery to estimate how such wood structural changes occur at the molecular level. The strain recovery after 1 hr steaming changed noticeably with the relative humidity of steam in the range between 60 and 80% irrespective of steaming temperatures. It should be noted that although plots of the strain recovery versus steaming time depended on the temperature and relative humidity of the steam, they could be superimposed by shifting them along the time axis by the shift factors of a_T and b_{RH} described below. From this, we obtained the following reduced strain recovery-time curve $g(t)$ at 180°C and 100% relative humidity.

$$g(t, a_T, b_{RH}) = 0.96 \times e^{-7.7\times 10^{a_T + b_{RT} - 2} \times t}$$

where

$$a_T = 0.03T - 5.4$$
$$b_{RH} = 0.0017H - 1.7.$$

t: steaming time (min), T: steaming temperature (°C), H: relative humidity of steam (%)

The apparent activation energy calculated from the shift factor a_T was about 26 kcal/mol which was comparable to the value of 23 kcal/mol from weight loss of wood by heating below 200°C[3)]. It is worth noting that the plots of the residual stress vs. strain recovery, both of which were measured at a time when the relaxation experiment ended, lay on the same curve at the respective relative humidity of steam. This indicates that the strain recovery is determined only by the residual stress at the respective humidity of steam regardless of relaxation time and temperature. We further observed that each curve between 0 and 100% relative humidity shows both features of dry heating (0% RH) and saturated steam heating (100% RH). From these observations, we obtained residual stress-strain recovery curves at any desired relative humidity of steam using interpolation. The combination of the reduced strain-time curve and the residual stress-strain recovery curve led to the residual stress at a given time at any desired steaming temperature and relative humidity. In addition, when compared at the same strain recovery in the residual stress- strain

*[1] A part of this work was presented at the 51th Annual Meeting of the Japan Wood Research Society in Tokyo.
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recovery curve, the residual stress changed remarkably around 60–80% RH with increasing relative humidity. From these findings, it was estimated that the wood cell wall structure, when steamed above 60%, changed as in saturated steam heating while below 60% RH it changed as in dry heating.

References

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